# THE RELATION BETWEEN THE CA II K LINE-CORE FLUX DENSITY AND THE MAGNETIC FLUX DENSITY ON THE SUN

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The flux in the emission line cores of the violet Ca II H and K resonance lines is often used as an indirect measure for stellar magnetic activity. The qualitative correspondence between the magnetic field strength and the brightness of the Ca II H,K plage -- which follows directly from a comparison of spectroheliograms and magnetograms (e.g. Leighton 1959, Howard 1959) -- demonstrates that the non-radiative heating is intimately related with the magnetic fields. Skumanich, Smythe and Frazier (1975) studied a quiet region to derive an empirical quantitative relation between the Ca II K and magnetic flux densities; they proposed a linear relation between the magnetic flux densities. We extend their study to solar active regions, and show that the relationship between $\langle fB \rangle$ and the Ca II H+K flux density can be described by a power-law fit with an index significantly smaller than unity.

We used the main spectrograph of the McMath solar telescope on Kitt Peak to record a Ca II K spectroheliogram and magnetogram of an active-region complex with a resolution of 2".4 x 2".4. (Livingston, 1968, described the instrument). The active-region complex, observed near disk centre on 22 October 1985, consisted of three distinct, adjacent bipolar regions. The total Ca II K plage area given in the Solar Geophysical Data was $2 \times 10^{10}$ km$^2$. The raster scan (completed in ~25 minutes) covered 390" x 540", or $2.8 \ 10^5 \times 3.9 \ 10^5$ km$^2$.

The Ca II K line-core intensity $I_C$ was measured relative to the line-wing intensity, $I_W$, in a window 7.39 A to the red (both with a 1.04 A wide passband). Schrijver et al. (1987) derive a calibration of the Ca II K line-core to line-wing intensity ratio to the Mt. Wilson Ca II H+K line-core flux measurements of cool stars expressed in arbitrary units (cf. Fig 1a).

## MAGNETIC FLUX DENSITY AND CA II K INTENSITY

Figure 1a compares the magnetic flux density $\langle fB \rangle$ to the relative Ca II K intensity pixel by pixel. We exclude pixels in sunspot umbrae or penumbrae and pixels near neutral lines. Despite the fact that the relationship between the Ca II K excess intensity ratio and the magnetic flux density appears to be nonlinear, the relationship does not change if the data are rebinned to pixels with a size of up to 6 x 6 times the original 2".4 pixels (Fig. 1b). The scatter about the relationship, however, is greatly reduced by rebinning. Schrijver et al. (1987) argue that this is due to the existence of a correlation length within which neither the magnetic flux density nor the Ca II K intensity show large systematic changes.

A diagram of stellar Ca II H+K fluxes versus colour shows a colour-dependent lower limit. Schrijver (1987) argues that the lower-limit flux is non-magnetic in origin and that it should be subtracted from the stellar flux in comparisons with other radiative diagnostics of activity. The quantity resulting from the subtraction of the empirical lower-limit from the observed stellar fluxes is called an excess flux. The lower-limit flux for a solar-type dwarf (B-V = 0.67) is $I_C/I_W = 0.13$ (Schrijver et al. 1987).

After subtraction of the lower-limit flux, the data in Figs. 1a and 1b can be fitted by a power law (cf. Figure 1c). When transformed to arbitrary flux units as measured by the Mt. Wilson HK-photometer the relation reads:

$$\Delta F_{CaII} = 0.051 \langle fB \rangle^{0.6} \qquad (1)$$

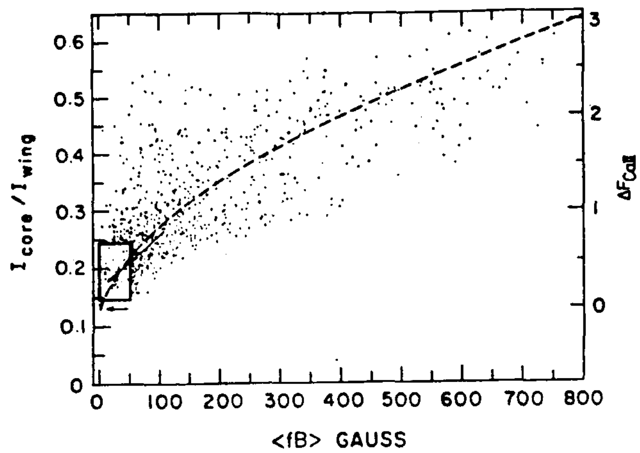


Figure 1 (a). Ca II K line-core over line-wing intensity versus magnetic flux density. The scale for the Ca II H+K excess flux density on the right is derived by Schrijver et al. (1987) to enable a direct comparison with Mt. Wilson arbitrary flux units. The line segment represents the result of Skumanich, Smythe and Frazier (1975) for a quiet region. The arrow indicates the level corresponding to the stellar lower-limit flux in Ca II H+K for a solar-type star. The dashed curve represents relation 1. Only 10% of the data points is plotted so that the dots remain resolved.

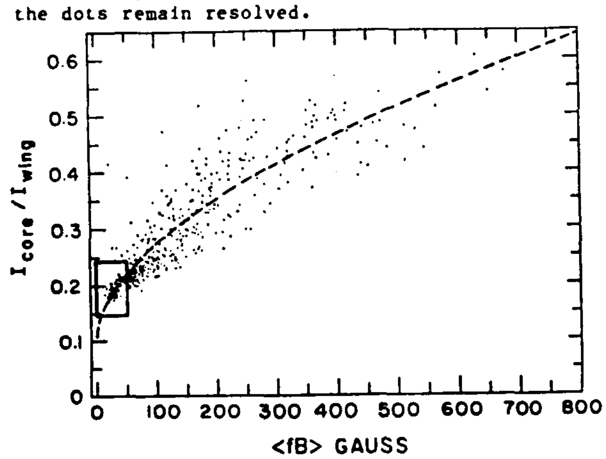


Figure 1(b) Same as Figure 1a, but after rebinning to pixels of 14".4 x 14".4. All data points have been plotted, but only a small fraction within the box.

where $\Delta F_{CaII}$ the Ca II H+K excess flux density. If the value of the lower limit is changed by 20% the exponent in Eq. (1) changes by 10%.

This relationship is valid for small pixels on the solar surface, and not necessarily for surface averaged stellar flux densities. In order to derive the relation for the surface averaged fluxes, the magnetic and Ca II H+K flux densities must be convolved with the (as yet unknown) distribution function of flux values for these quantities.

DISCUSSION

A quantitative relationship between the radiative losses from the stellar outer atmosphere and the photospheric magnetic flux for cool stars has been established only recently (Schrijver and Saar 1987):

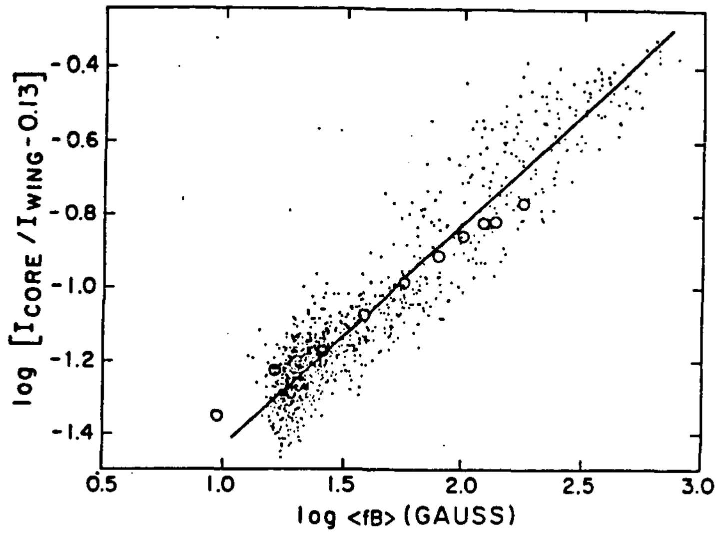


Figure 1(c) Ca II K excess intensity ratio (i.e. after subtraction of a minimal intensity derived from stellar data) vs. the magnetic flux density. The power-law fit of Eq. 1 is shown. The open circles mark the binned data of Skumanich, Smythe and Frazier (1975; their Table 3).

$$\Delta F_{CaII} = 0.055 \langle fB \rangle^{0.62} \quad (2)$$

This power law fits the solar and stellar data provided <fB> < 300 Gauss. The stellar Ca II H+K excess flux density appears to saturate when the stellar magnetic flux density exceeds ~300 Gauss (Schrijver and Saar, 1987). Note that Figure 1 suggests a similar saturation for solar data.

Equation (1), derived for small elements on the solar surface, is remarkably similar to Eq. (2) for stars. The equality of the solar and stellar relations supports two major conclusions: a) radiative losses from individual small areas on the solar surface apparently behave as the surface-averaged atmospheres of cool stars of different levels of activity, and b) if the Sun moves up and down along a line described by Eq. (2) during its activity cycle (see Schrijver and Saar 1987), the invariance of the solar Eq. (1) to surface averaging at different levels of activity puts severe restrictions on the change of the distribution function of magnetic flux densities over the solar surface throughout the activity cycle (see Schrijver et al. 1987).

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